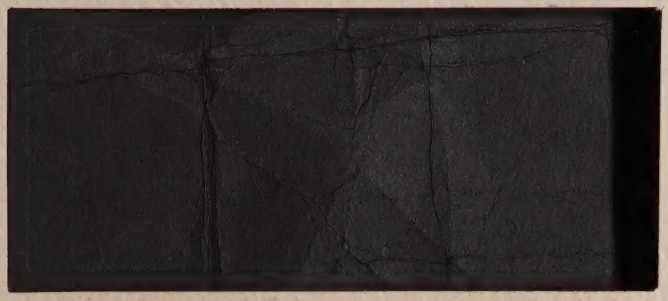
VL/A

INSTRUCTION MANUAL



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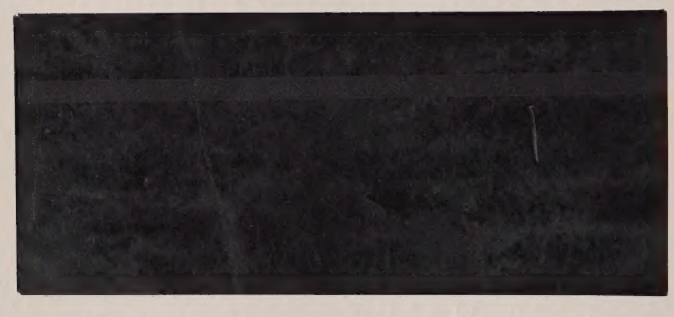

TYPE 400A SERIES
VOLTMETER

SERIAL NO. _____

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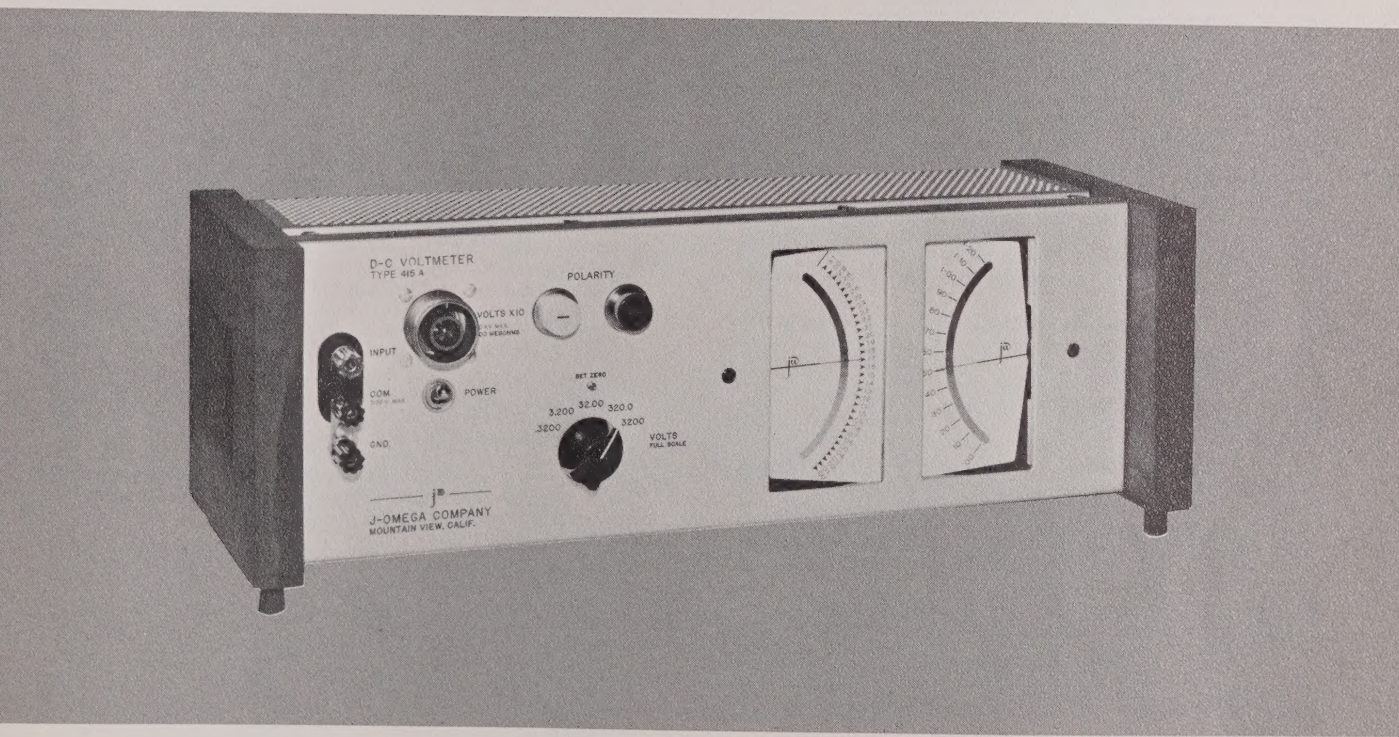
TYPES 413A AND 415A DIGITAL/ANALOG 0.1% DC VOLTMETER

For Low and High Voltage Measurements



USES

GENERAL LAB INSTRUMENT — High accuracy and stability combined with unusually broad voltage ranges.

RECEIVING INSPECTION — Single control operation, automatic polarity display, isolated input provide desirable measuring speed and versatility.

POWER SUPPLY ADJUSTMENTS AND MONITORING — Resolution to tenths of a millivolt and visual analog "follow" for observing power supply drift.

SYSTEMS INSTALLATIONS — Available as a compact, rack mounting unit with input terminals at front or rear.

UNATTENDED MONITORING — Recorder output option permits unattended long-term measurements and provides permanent record.

CIRCUIT DESIGN — High input impedance, low drift, fast response fulfill suitability as a valuable design tool.

PRODUCTION LINE TESTS — Constant display, digital/analog readout and linear scales contribute to fast, foolproof testing.

TWT VOLTAGE MEASUREMENTS — 3200 volt range permits direct use for helix voltages, etc.; 1000 volts floating is standard.

FEATURES

COMPLETE OVERLOAD PROTECTION — Accidental application of maximum kilovolt rating in any range setting will not damage instrument.

HIGH RESOLUTION — Exceeds .03% of full scale; 0.1 millivolt on the 320 millivolts range.

DIGITAL/ANALOG MEASUREMENT — The combination offers the user advantages of both techniques.

AUTOMATIC OPERATION — No balancing operation as with potentiometric type instruments; polarity indication is automatic also.

UNIQUE RECORDER OUTPUT — Recorder traces both digital and analog data on strip chart; provides all four digits of information.

CONSTANT DISPLAY — Magnitude and direction of input changes are seen immediately; no sampling time delay.

WIDE MEASURING RANGE — Full-scale ranges from 320 millivolts to 3200 volts makes these instruments exceptionally useful.

FAST READOUT — All readings made from same close-positioned linear scales; no scale selection is ever necessary.

10 KILOVOLT VERSION — Special high voltage unit for direct measurements to 10 kV; provides constant input impedance of 100 megohms.

DESCRIPTION

Two objective questions about these J-Omega instruments in a prospective user's mind often are— what is a Digital/Analog Voltmeter and, what are its advantages?

Types 413A and 415A are broad range voltmeters for DC measurements from a few tenths of a millivolt up to as high as 10kV. In both models all range positions are damage-protected against excessive voltages that may be applied accidentally.

The instruments measure and display about 85 to 95% of an unknown input value in true digital form and indicate any remaining increment as an analog vernier that is immediately responsive to the dynamic characteristics of the input. Users find the combination of digital and analog techniques offers several practical advantages when compared with other instruments of either the straight analog or digital type in that: a single control selects both function and range for any operation; there is no null-balancing procedure; readout is fast and foolproof, since the same pair of **linear** scales is used for all measurements; a changing input does not produce unreadable digit-hunting common to full-digital instruments; and the J-Omega instruments do not sample the input but instead, measure and display it continuously.

These factors provide exceptional "operating rapport" when using the 413A or 415A because the measuring feel of an analog instrument is retained, coupled with the operating simplicity and readout ease of digital equipment; this becomes quite apparent when making the first few measurements with an instrument. These unique instruments are broad-range voltmeters combining the accuracy of a Standards lab instrument with the ruggedness and versatility of an "everyday" multi-range meter. Proper uses include both the engineer's bench and production line where they can be used for routine measurements by semi-skilled persons even when the accuracy capabilities are needed only occasionally.

Two conventional D'Arsonval movements are used, and so arranged that the "resolving power" of one acts to multiply the resolution and accuracy of the other. When an input is applied, the right-hand indicator smoothly moves up the scale until, in the region of full scale, the digital (left) indicator abruptly moves up one step and the right-hand meter drops back to the bottom of its scale. This process is repeated very rapidly until the correct reading is reached within about one second.

The analog meter is calibrated so that the span from 00 to 100 corresponds to 1 step of the digital indicating meter. Since the 00 to 100 span of the interpolating meter is 1/32 of the instrument's range, this results in an improvement of resolution of the D'Arsonval movement by a factor of 32! Movement of the left-hand meter pointer is quantized so that it always points directly to one of 32 numbers (00 through 31) thus providing a true digital indication.

Emphasis was placed on reliability and simplicity in designing these digital/analog instruments. The instruments are transistorized. A field effect transistor input circuit maintains a high and constant input impedance to minimize loading of the source being measured. Particular care has been taken to conservatively select and utilize components well within their ratings as a means to assure trouble-free operation over long periods.

OPERATION

Operating and reading the 413A or 415A is very simple and fast. The single control is used initially to select the range. Measurements are then made automatically, including color-coded pilot light polarity indication.

The 415A has an additional high voltage input circuit which serves as a "times 10" multiplier with 100 megohm input impedance for any of the five basic full-scale ranges. With the range switch in the "3200V" position, measurements up to 10kV can be made using this input.

For readout, the operator simply reads from left to right, obtaining two figures from the left-hand digital indicator and two additional figures from the right-hand indicator. A typical readout might be 23-13 or 2313. In the "320.0mV" range, this would indicate 231.3mV with a resolution of 0.1 millivolt or better!

When conventional accuracy (1 or 2% of full scale) is required, the instrument may be set to the highest range needed so that range switching is completely avoided. For example, work in transistor circuits might seem to call for frequent use of the 3.2 volt range but the right-hand meter resolves 10 millivolts on the 32 volt range. Thus, a single range will cover the highest voltage to be encountered while offering good accuracy on low voltages.

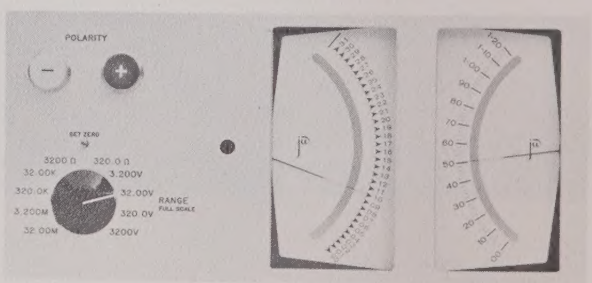
The recorder output option drives single and dual channel recorders. When used with the latter, the readout of both meters is traced on a single chart; this provides complete 4-digit, unambiguous digital/analog recordings.

CIRCUITRY

A signal voltage proportional to the input is obtained from an input amplifier. This voltage is applied to a binary digitizing circuit that produces a nearly equal voltage quantized in 32 very accurate steps of 0.2 volt each. The left-hand meter is fed from the quantized voltage so that it moves in discrete steps, forming a digital indicator. The right-hand meter indicates the difference between the signal voltage and the quantized voltage. It thus interpolates between the steps of the first indicator.

Circuitry is comprised of three main sections: (1) an input D-C amplifier with associated range resistors. (2) a six-stage binary digitizing circuit which provides a five bit (0 to 31) digit signal plus one bit of polarity (+ or −) information, and (3) a highly stable regulated power supply.

The input amplifier is a four stage single-loop feedback circuit in which the first and second stages are balanced. The digitizer consists of six similar stages, each composed of a balanced pair of transistors for voltage comparison. A precision resistor network provides digital-to-analog reconversion to produce a quantized voltage approximating the input amplifier's output. The power supply reference voltage, obtained with a precision temperature-compensated Zener diode, has a temperature coefficient of approximately ±0.001%/°C.



A READING OF 10.80 VOLTS (VOLT-OHMMETER PANEL SHOWN)

SPECIFICATIONS

RANGES Type 413A: ±320.0 mV, ±3.200 V, ±32.00 V, ±320.0 V, ±3200 V.

Type 415A: ±320.0 mV, ±3.200 V, ±32.00 V, ±320.0 V, 3200 V, ±10 kV

ACCURACY ±0.1% of full scale or better. (The total accuracy for both resistance and voltage measurements improves linearly from ±0.1% f.s. at the top of each range to ±.03% of f.s. at bottom of each range, i.e., accuracy of any measurement is ±.07% of reading plus ±.03% of f.s.).

INPUT IMPEDANCE Constant 10 megohms ±0.2% all ranges to 3200 V; plus on 415A 100 megohms when using the "X10 Input".

INPUTS 3-terminal jack-type posts. Common terminal may be floated ±1000 V above case; 415A has additional floating high voltage connector.

BREAKDOWN PROTECTION Maximum rated kilovolts may be applied through appropriate input in any range setting without damage to circuitry or meters.

DRIFT First hour after turn-on approx. 10 mV max. on 320 mV or 3.2 V ranges and 0.1% f.s. max. on other ranges; thereafter, one-tenth of above figures max. per day in uniform ambient. Panel zero-adjuster permits immediate correction.

RESPONSE TIME Full scale negative to full scale positive approx. 1 second; except on 3.2 V and 320 mV ranges approx. 2 seconds.

AC REJECTION Up to 10% of full scale range setting 60 Hz to 100 kHz; to 100% on the 3.2 V and 320 mV ranges.

DIMENSIONS Bench: 5¾" H × 16⅝" W × 6¾" D. Rack: 5-7/32" H × 19" W × 5⅝" D.

WEIGHT Net 9 lbs., shipping 14 lbs.

POWER 105 to 125 volts AC, 50 to 1000 Hz, 25 watts.

REPRESENTED BY:

J-OMEGA COMPANY
2271 MORA DRIVE • MOUNTAIN VIEW, CALIF. • (415) 961-2000

Printed in U.S.A.

Notes On High Voltage Instruments

Types: 215A and 215A-16
219A and 219A-16
415A and 415A-16

Voltage Rating

The standard instruments are rated for 10 kV maximum input, and the -16 versions are rated for 16 kV. This rating limitation applies to the total of DC plus instantaneous peak AC. In cases where significant amounts of AC are present, the applied DC must be restricted to lower than rated values.

The standard and -16 versions of these instruments have slight differences in insulation, but differ principally in testing and calibration.

The -16 versions also have a 100 megohm input resistor that is specially selected for low voltage coefficient.

Accuracy

The accuracy of the instrument with the X10 input is computed in just the same way as the accuracy is computed for the standard input. For this computation, the 10 or 16 kV input voltage limitation is ignored, and the accuracy is computed as it would be for a 32 kV range.

The X10 input may be used with the low voltage ranges as well as with the 3200 V range. In this way, advantage may be taken of the 100 megohm input impedance even for low voltage measurements. Some loss of accuracy will occur, however, when the X10 input is used with the 320.0 mV range of the 219A and 415A series instruments; no accuracy guarantee is made for this combination of input and range setting.

Caution

The high voltage connector and wire supplied with these instruments are rated for 20 kV breakdown. They should not, however, be relied upon for personnel or equipment protection at high voltages. The user should exercise extreme caution in setting up these instruments, so as to avoid danger to personnel and damage to other equipment in case of failure of any part of the system.

INTRODUCTION

This instruction manual covers the use and maintenance of the various models comprising the Digital/Analog Series referenced on the title page. Information about the specifications and performance features provided by a specific model is shown on the product bulletin enclosed in this manual.

All models of J-Omega Digital/Analog instruments combine, in a single unique package, the circuitry and operating features of both digital and analog instruments. Four places of information are provided with an accuracy of 0.1% of full scale or better. The left meter indicates the digitized data, which usually comprises 85% or more of an input's value; the remaining increment is displayed in analog form by the right meter. Operation of the instrument is fully automatic, after the appropriate measuring range is selected. It is significant to note that there is no plus or minus one count error factor to add to the basic accuracy statement of the instrument.

Welcomed protection is provided in measuring voltages where, even the lowest range (320 mV or 3.2 V) will sustain accidental application of overloads to 3.2 kV without damage to the circuitry or meters. Nevertheless, the application and handling of this instrument should be made with the reasonable respect due any precision device. Avoid floating an input voltage above 1000 volts as noted on the instrument's panel. In particular, with resistance measuring models, care should be taken not to apply voltage in the resistance measuring mode; these ranges are marked in red as a precaution.

Due to its unusual features, the Digital/Analog instrument makes a fine general purpose laboratory instrument for the intermittent use common to this type of application. There is no reason, however, why the instrument should not be used as an all day, month-after-month production test unit. It is designed to, and has proven to give reliable extended performance with minimum need for service and calibration in such applications.

INSTRUMENT WARRANTY

J-Omega instruments are covered by a one year warranty, the terms of which are stated below.

WARRANTY

J-Omega instruments, and components thereof, are warranted to be free from defects in materials and workmanship for one year from the date of initial factory shipment.

We, or an authorized representative will fully repair equipment of our manufacture covered by the warranty terms on a no-charge basis, to include both parts and labor.

Applications misuse, abuse of the equipment, or unauthorized repair will void this warranty and our obligation to provide no-charge services. J-Omega Company is not liable for consequential damages.

Prior to returning an instrument to the factory for service, please contact J-Omega Company, either directly or through our representative and indicate the nature of the difficulty being encountered. The problem may be one which can be resolved quickly and easily in the field, thereby eliminating the time loss involved in transportation to and from the factory. Instruments sent to the factory should be shipped prepaid.

When non-warranty repairs are to be made, we will notify you of the estimated charges before proceeding with the work.

OPERATING INSTRUCTIONS

Preparation

The bench version of the instrument can be placed on its bottom or, if reading convenience makes it desirable, on its back. When used in the normal position the bottom front feet which are threaded into the end blocks, can be extended about 1-1/4 inches to reduce the viewing angle. Rack mounting models fit the standard 19 inch relay rack scheme. Input connections may be located on the rear depending on whether or not this optional feature was ordered.

Application requirements should dictate the user's selection of appropriate input leads, test prods, clips, etc. Models equipped with the special high voltage (10 kV) input are furnished with the mating cable connector. In making up a cable be sure to use wire with a suitable high voltage rating.

Before plugging the unit to power source, note the required nominal input voltage marked on the rear of the instrument. The standard (115 volts) instrument can be powered from AC sources providing 105 to 125 volts, 50 to 1000 Hz. A 220 volt instrument is suitable for use from 210 to 250 volts, 50 to 1000 Hz.

Panel Controls

Meter Zero Setting: Two mechanical zero adjustments are accessible through holes in the front panel, one next to each meter. The need to make this adjustment should be rare. This zeroing should only be done when the power has been off for several minutes or more. Set each meter pointer exactly on the "zero" marker line using the mirror-back feature of the meter to avoid parralax error.

"POWER" Switch: The instrument is turned on by moving the lever up. Before doing so it is advisable to make sure that both meters are properly mechanically "zeroed". There is no warmup time waiting required before making measurements, however, at turn-on it is best to check the electrical "zero" before proceeding to make measurements.

"SET ZERO" Control: After turn-on this control should be rotated so that both meters are zeroed electrically. This should be done only on the lowest (3.2 volt or 320 mV) range and with the input terminals shorted (resistances up to 2 or 3 megohms are adequate "shorts"). If only one voltage range is to be used, the instrument may be zeroed on this range.

The electrical zero should be checked occasionally and readjusted as necessary during the first hour or so after turn-on. After this zero drift should become negligible.

NOTE: Do not use the "SET ZERO" adjustment to obtain offset, as errors may result. In particular, for those models designed to measure resistance, this control should not be used to compensate for ohmmeter lead resistance. Lead resistance when significant, should be measured as a separate step and subtracted from the ohms reading.

NOTE: The high resolution of this instrument can be very useful, but the operator should not be misled into making too-frequent or too-exacting adjustment of the "SET ZERO" control. Small errors may be quite visible yet negligible.

"RANGE" Switch: Select a range that is at least slightly higher than the highest anticipated input value. In the Type 200 Series this switch permits selection of both ohms (Ω, K, M) ranges and volts (V or mV) ranges.

Type 217 and 219 have a two-position toggle switch added to the front panel next to the "RANGE" switch. When the main "RANGE" switch is in its lowest voltage setting, this toggle is used to select between the "3.200V" range and the "320.0mV" range. The selector toggle has no effect when range switching to any of the other voltage and resistance ranges.

CAUTION: As is the case with most ohmmeters, resistance measuring models may be damaged by application of excessive voltage to the ohms circuitry. Be sure to use the ohms settings only when testing passive devices.

Input Terminals: The "INPUT" (red) terminal is the independent terminal when voltage is measured. It is well insulated against high voltage and leakage. This terminal is positive in resistance measuring models.

The center "COM." terminal connects to the bulk of the internal circuitry and has somewhat lower insulation to the ground. Whenever possible it should be grounded to the "GND." terminal, which is connected to the case and panel. If the common terminal is to be floated from case ground, it is important that the potential between these two terminals not exceed the floating "MAX" noted on the panel.

The upper two terminals of the instrument are used for both voltage and resistance measurement. For voltage measurements, a "+" polarity indication means that the top terminal is positive with respect to the center terminal. The input impedance is a constant 10 megohms ($\pm$.2%).

"VOLTS X 10" Input: Some models are provided with additional capabilities to measure up to 10 kV, with a higher input impedance, by means of using this special high voltage input which supplements the red "INPUT" terminal.

The "VOLTS X 10" input multiplies the range of any of the main voltage ranges by a factor of 10 and provides 100 megohm input impedance for these ranges. The "320.0V" range may then be used to measure up to $\pm$3,200 volts; however, the "3200V" range should not be used with inputs higher than $\pm$10,000 volts, as is noted on the front panel of the instrument.

Inputs utilizing this connector may be floated to the "MAX" voltage specified for the "COM" terminal that is, $\pm$1000 volts by disconnecting the link between the two black input terminals.

"POLARITY" Lights: These are in the form of pilot lights marked "+" and "-". They serve to indicate when the instrument is turned on as well as to indicate the polarity of a DC input. An indication of either "+" or "-" may be obtained when the input is zero.

Measurement Readout

Read left to right four (4) digits, two from each meter to obtain four places of information. Place the decimal as it is located in the range setting. If the right-hand meter reads 1-00 or above, the "1-" alone should be added (transferred) to the reading of the left-hand meter.

Examples: A reading of 27 and 1-03 is read as 2803

A reading of 08 and 65 is read as 0865; on the "32.00V" range of the instrument this would indicate 08.65 V. (By retaining the first 0, the decimal is easily placed after the second figure just as it occurs in the range setting.)

When using the "VOLTS X 10" input, shift location of the decimal point one place to the right for all voltage measurements.

NOTE: In the measurement process the right-hand meter does not scale to 1-20. Normally, the high-scale "switch-point" is in the vicinity of 1-02 to 1-08 after which the pointer resets down exactly 100 (i.e., 02 to 08) as the input value continues to increase. Also, in resistance measuring models it is normal for open inputs to cause the right-hand meter to go off scale on resistance range settings.

Recorder Output (optional)

Two pairs of terminals are provided on the rear of the instrument to drive a dual pen (overlapping) or dual channel potentiometric recorder. Dual traces will provide records of the instrument's complete four-place readout. The digital meter's output gives the most significant numbers traced on an appropriate chart as distinct digital indications of: 1, 2, 3 or 4, etc.....up to 31. The analog trace shows two additional digits of information in analog form thereby recording, as an expanded scale, the minute changes of the input. Readout can be made anywhere along the chart by noting the digital and analog indications, just as when reading the meters visually.

A single channel recorder can be used to monitor only the analog meter's output. Even then, the value of the now unrecorded digital indication can be determined at any point along the chart. Simply jot down the digital readout when starting to record; later note the direction of (up-scale or down-scale) the analog meter's "resets" and thereupon add or subtract a "one" to the original digital reading for each reset traced up to the area of interest on the chart.

Outputs of the instrument are scaled for use with a 10 mV recorder span (10 mV full scale). Inputs should be isolated (floating) and have an impedance of 1 K or more. To directly read the range in which the analog meter operates without recalibrating the recorder, the chart paper should be graduated from 0 to 120. The recorder channel fed by the digital meter will track between 0 and 31 on the same chart. Charts graduated to at least 110 and somewhat higher than 120 may also be directly read by recalibrating the recorder's span.

THEORY OF OPERATION

Input Amplifier

The input amplifier is a transistor circuit having high gain stability by virtue of a large amount of negative feedback and stable feedback resistors. The amplifier consists of a field-effect transistor, FET 1, and transistors Q1 through Q4. FET 1 forms a "source follower" stage which is biased to obtain low drift with changes in temperature. This stage "transforms" the high input circuit impedance for driving the second stage. The second stage is balanced, consisting of two transistors with a common large emitter resistor. These two transistors are thermally joined to minimize the possibility of drift from thermal effects. The succeeding two stages are single ended.

Gain is controlled by varying the resistance in the feedback path. When the instrument is used as a voltmeter, "RANGE" switch S1 selects one of several paths consisting of stable precision resistors. In instruments that operate as an ohmmeter, these same range resistors are used to furnish a constant input current to the junction of R8 and R10. Feedback then is obtained through the unknown resistor in such a way that the current through the unknown just balances the constant current through the range resistor. The resulting voltage drop across the unknown appears at the output of the amplifier to be measured by the digitizing and readout circuitry.

The input amplifier inverts the polarity of the input. When an appropriate range is selected, the amplifier's gain will be such as to produce an output voltage which will be between -6.4 and +6.4 volts. In the following explanations the term "signal" is the inverted output from the amplifier. Thus a full-scale input voltage or resistance on any range produces a 6.4 volt signal which is negative when the input voltage is positive and vice versa. For various voltage ranges the amplifier has gains such as -2, -.2, -.02, etc.

Digitizing And Readout Circuits

The signal voltage from the input amplifier is broken down into 64 steps of 0.2 volt each by successively comparing it to six voltages obtained from a resistor matrix, R105, R106, and R135-R162. The first such comparison is with a "0" voltage obtained from R105 and R106. This comparison determines the polarity of the input signal by determining whether the output of the input amplifier is above or below 0 volts.

The result of each comparison is a decision of whether or not to actuate a relay which then adds or subtracts to the voltage for all the following comparisons. Thus if the first comparison detects a negative signal voltage (corresponding to a positive input) relays K101 and K102 are actuated and resistors R157-R159 produce a voltage of -3.2 volts for the next comparison. If the signal voltage had been positive, this second comparison voltage would instead be +3.2 volts.

Similarly, the result of the second comparison determines the position of another relay, K103, which adds or subtracts an additional 1.6 volts to produce a third comparison voltage ($\pm$3.2, $\pm$1.6 volts) from resistors R153-R156. This process is repeated until, after six such comparisons, the signal voltage from the input amplifier is determined within 0.2 volt.

The resulting positions of the relays express the binary numbers from 000000 through 111111. The numbers 100000 to 111111 correspond to inputs of one polarity, while the numbers 000000 to 011111 correspond to inputs of the opposite polarity. The first of these digits, 0 or 1, is displayed as polarity information by the pilot lights. The remaining 32 numbers from 00000 to 11111 are displayed as 32 discrete positions of the left-hand meter. This is done by

connecting weighting resistors to the relay contacts so that each relay contributes to the deflection of meter M102 according to that relay's binary value. Resistors R135-R141 and R160-R163 are used for this function also.

Another set of weighting resistors, R109 and R127-R132 produces a similar quantized voltage for comparison with the signal from the input amplifier. Meter M101 is connected to read the difference between this quantized voltage and the signal voltage from the input amplifier. It thus provides an indication of the difference between the signal voltage and the value indicated by the step-wise meter, M102. It follows that the sum of the meter readings is proportional to the input voltage or resistance.

An understanding of the comparison circuits can be had by considering one of these six circuits separately. We may consider Q116-Q118, R124 and R125, which together form the comparison circuit that drives relay K107. A nearly-constant current of 1 ma is fed to the emitters of Q116 and Q117. Only one of these transistors will conduct, the one which has the more negative base voltage. But the base voltage of Q117 is the signal from the input amplifier while the base voltage of Q116 is a comparison voltage obtained from R135-R141. Thus Q117 will conduct only if the signal voltage is below the comparison voltage, otherwise Q116 will conduct. When Q117 conducts it drives Q118 into conduction and this in turn causes relay K107 to operate.

As an example, the events which take place in measuring a positive input to the instrument that produces -5.5 volts signal to the digitizing and readout circuitry are as follows:

> The positive input (which might be +275 V with the "320V" range for example) is inverted by the amplifier so that -5.5 volts appears at the base of the right-hand transistor of each comparator pair.
>
> Decision 1, -5.5 V at the base of Q102 is below "0" volts at Q101 therefore K102 is energized; providing -6.4 volts that is divided to -3.2 volts in resistors R157, 8, 9 for the succeeding comparator; the red (plus) lamp lights and proper polarization is provided to meters by energizing K101. This relay action also contributes -3.2 V to the third comparator's reference through R155, to the fourth comparator through R150, etc.
>
> Decision 2, -5.5 V at Q105 is lower than -3.2 V at Q104 so K103 is energized; -1.6 V is contributed to remaining comparators and the meters.
>
> Decision 3, -5.5 V at Q108 is lower than -4.8 V at Q107 so K104 is energized; -.8 V is contributed to remaining comparators and the meters.
>
> Decision 4, -5.5 V at Q111 is not lower than -5.6 V at Q110 therefore K105 is not energized; +.4 V is contributed to remaining comparators and the meters.
>
> Decision 5, -5.5 V at Q114 is less than -5.2 V (sum of -3.2, -1.6, -.8, +.4) at Q113 so K106 is energized; -.2 V is fed to Q116 and the meters.
>
> Decision 6, -5.5 V at Q117 is lower than -5.4 V therefore K107 is energized contributing -.1 V to the meters.

In addition to the above, R109 contributes a +.1 V offset to M101. (A plus .1 V offset is provided for <u>all negative signal</u> voltages i.e., positive input voltages and vice versa. This is necessary to permit quantized voltages as low as 0.)

Totaling the voltages, we have available to M101:

	-3.2 V from K102 through R127
	-1.6 V from K103 through R128
	-0.8 V from K104 through R129
	+0.4 V from K105 through R130
	-0.2 V from K106 through R131
	-0.1 V from K107 through R132
	+0.1 V from R109
Total	-5.4 V

M101 presents the difference between this -5.4 V and the -5.5 V signal voltage as a scale indication of 50. M102, the "digital" left-hand meter presents just the -5.4 V quantized signal as a reading of 27. Thus we read 27-50 on the two meters and interpret this, according to the selected range, as an input of 275.0 V, 2.750 V, 2.750 megohms, etc.

Regulated Power Supply

A zener reference diode, CR205, is in one arm of a bridge consisting also of R217, R218, R220 and R222. R217 is a fixed resistor selected at the factory to set the power supply output to ~~21.8~~ 12.8 volts (measured from -6.4 to +6.4 volt points). The output of the bridge is connected directly to the bases of Q207 and Q208. These balanced transistors amplify the error signal and feed it to Q204 and Q205 which in turn amplify the signal and apply it to Q203, thence to the series transistor Q202 which couples the rectifier output to the regulated +6.4 volt line.

The junction of R219 and R221 is midway between the +6.4 and -6.4 volt lines and, therefore, is used as the "0" volt reference with respect to which all other voltages are measured. Note, however, that this junction has an output impedance of 2000 ohms so that any measurements made from this reference should be made with a high impedance meter; preferably ten megohms or more. Also note that this "0" voltage reference is connected to the center input terminal on the panel only when the range switch is at a VOLTS setting. Thus the center input terminal should not be regarded as an electronic ground for maintenance measurements of the instrument's circuit; instead, find the junction of R219 and R221 and use this as a "0 volts" reference.

An additional regulated power supply is used to supply +50 volts to the comparison circuits and the low-voltage regulator. Here again an error voltage is obtained from a bridge. In this case the 12.8 volt output from the low voltage supply forms one arm of the bridge, the high voltage supply forms another arm and R215 and R216 form the remaining two arms. The bridge output is applied to the base of Q206 which acts as an emitter follower to drive series transistor Q201. Q201 provides variable coupling from the negative output of the rectifier circuit to the +6.4 volt line so that the high voltage supply is effectively in series with the low voltage supply.

Resistor R224 and silicon rectifier CR206 are in series with the negative lead from the low voltage rectifier circuit to provide additional negative voltages of -7.1 and -8.0 volts. These voltages are not critical and are not highly regulated. CR206 is operated only in its forward direction to give a voltage drop of about 0.7 volt; it does not act as a rectifier.

MAINTENANCE AND REPAIR

Periodic Maintenance

This type of maintenance is not required other than to provide assurance of the calibration accuracy of the instrument.

It is recommended that a regular check of calibration be performed to provide the user assurance that the calibration is correct. The frequency of such checks will depend upon the level of confidence that is desired. Simple checks against a fixed resistor or standard voltage can be made daily if desired.

Complete calibration might be anything from a monthly to an annual process. In any case, the following procedure is recommended.

Calibration And Checkout

1. Remove rear cover. Set front-panel mechanical zero adjustments of meters with meter terminals shorted and with power off. It is very important that this be done accurately.

2. Check voltage from -6.4 to +6.4 volt lines (available at R219 and R221); it should be between 12.79 and 12.81 volts. Replace trim resistor R217 with an appropriate value *stable* resistor between 0 and 56 ohms if necessary.

3. Set R160 (500 ohm trimmer, rear board) to calibrate left-hand meter (M102). Using a variable input, set this trimmer so that all 32 meter positions are distinct and unambiguous. To do this it may be necessary to compromise so that pointer is slightly low on some steps and slightly high on others.

4. Using a small input voltage so that the analog meter (M101) reads just above 100, set R108 (50 ohm trimmer, rear board) so that the M101 drops exactly 100 points as M102 steps from 00 to 01. Do not vary the input to obtain the step; short Q118 from base to either collector or emitter to cause the step to occur one way or the other.

5. Check operation of relays. Switching must occur above 00 and below 1-20 as read on M101 when going both up scale and down scale. Normally, the switch-points will be between about 02 and 08 and between 1-02 and 1-08.

6. Check accuracy of resistor set R109 and R127-R132: With instrument carefully zeroed on highest voltage range, cause the polarity indication to reverse by shorting Q103 from base to either emitter or collector. A shift from zero of more than about 1/2 division on the right-hand meter indicates the need for a high-resistance trimming resistor shunting R109 or R127 (depending on direction of shift). Such a resistor should not be lower than about 100 kilohms. Large shifts (several divisions) may indicate need for replacing the set R109 and R127-R132. Before trimming or replacing these resistors make sure that the error is not due to excessive relay contact resistance, especially in K102 and K103. Printed circuit pads are provided for a trim resistor paralleling R127.

7. Check for input current. Switch from "3200V" range to "3.200V"range with input open. Right-hand meter should move less than one division.

8. With input shorted, move the range switch from the "3200V" position to the "3.200V" position after the instrument has been carefully zeroed. Any shift from zero can be corrected by adjusting trimmer R228.

9. Type 200 Series - Calibrate resistance ranges. Use fixed precision resistors near 320 ohms, 3200 ohms, 32 K, etc., as references. Calibration trimmers are on front circuit board as listed. (Note: follow order shown as R21 and R23 will affect all ohms ranges higher than 3200).

Range	Trimmers
320.0 ohms	Fixed - replace R20 if necessary
3200 ohms	Fixed - replace R21 or R23 if necessary
32.00K (3200V)	Fixed - replace R15 if necessary
320.0K (320V)	R18
3200M (32V)	R17
32.00M (3.2V)	R16
all VOLTS	R8 (see below)
320.0mV	R46 (see below)

Using an accurate voltage source of 300 or 320 volts, set the "320.0V" range using trimmer R8. Check accuracy of other voltage ranges.

On Types 217 and 219 it is necessary to calibrate the "320.0mV" range as the last step, after R8 has been correctly set. For this step, use a precision input of 300 to 320 mV and trim R46.

If voltage measurements are more important than resistance measurements, it is now permissible to readjust R16-R18 slightly to improve accuracy of voltage readings. It should not be necessary to change these enough to destroy the accuracy of the ohms range.

Type 400 Series - Calibrate voltage ranges. Use a precision voltage source (.01%) having the following voltages: 3000 or 3200 V, 300 or 320 V, 30 or 32 V, 3.0 or 3.2 V and 0.30 or 0.32 V.

Calibration trimmers are on front circuit board as follows:

Range	Trimmers
3200V	R8 (adjust first as it affects all ranges)
320.0V	R18
32.00V	R17
3.200V	R16
320.0mV	R46

10. See page 14 for high voltage calibration of Types 215, 219 and 415.

Trouble Shooting

In trouble shooting, the rear circuit board may be removed and laid on the service bench without disconnection. This will make nearly all parts of the instrument highly accessible while the instrument is operating. This may also be done during calibration to make the calibration adjustments more accessible. For trouble shooting it is recommended that a high-impedance voltmeter is used. Preferably 10 megohms or more. (For step 2 above it is permissible to

use an accurate type low-impedance meter.)

NOTE: The center input terminal ("COM") is connected to the "0" volt reference only on VOLTS ranges. When trouble shooting, clip on to the junction of R219 and R221 to obtain the "0" volt reference; do not use the center input terminal.

Probably the most common cause of failure is a shorted transistor, Q4, caused by applying an excessive input voltage when the range switch of resistance measuring models is set to a low ohms range. When Q4 is shorted, the instrument continually reads off-scale positive. Q4 has been provided with a socket for easy testing and replacement. Further damage may occur if the input voltage is very high or if high input current is available, but this is more rare. Other components subject to damage include Q101 through Q118 and the range resistor involved (such as R21 and R15).

The following transistors are matched pairs and should be replaced as pairs. Pairs are available from J-Omega Company:

Q1 and Q2 (joined)
Q101 and Q102
Q104 and Q105
Q107 and Q108
Q110 and Q111
Q113 and Q114
Q116 and Q117
Q207 and Q208 (joined)

Any of these pairs may be replaced independently of the other pairs.

Transistor pairs are matched for equal ($\pm$2 mV) base-emitter voltage at 1/2 ma collector current, at equal temperatures. Transistors are selected for h_{FE} of 100 or greater.

Relay covers may be removed for contact cleaning and adjustment. Cleaning should be considered whenever erratic readings are obtained. Starting with relay K102, the lowest numbered relays carry the most current for the resistor matrix and are therefore most subject to contact voltage drop. Paralleled pairs of contacts drive the resistor matrix, although for simplicity they are shown as single contacts on the schematic diagram.

Relay Cleaning And Adjustments

IMPORTANT NOTE: The need to adjust relays should be rare. The relays are carefully adjusted at the factory and are designed to operate millions of times (years) without further adjustment. If relay problems are suspected, clean contacts first, then check to see if they operate as described below; adjust only if necessary.

Relay contacts should be bright and clean. Use clean lint-free paper to polish surfaces so as not to remove the gold plating. Do not use a burnishing tool or sandpaper as this will expose the underlying silver and permit tarnishing.

K101 and K102 - Contact sequencing described here is important for K102. To provide interchangeability K101 should also be sequenced. It is not practical to recommend exact gap measurements since mechanical tolerances cause individual relays to differ somewhat; therefore, it will depend upon the good judgment of the technician to determine the correct gaps. When adjusting gaps, bend only the stiffeners, never the contact spring leaves.

With the cover removed, insert a small screwdriver between the plastic base and the horizontal tab of the armature. A levering action on the screwdriver will operate the armature to open and close the contacts while making adjust-

ments. Start with the set of contacts connected to Pins 14 and 16. This set is in the meter circuit and must "break" before the other three sets and also "make" last. By slightly bending the stiffener tabs, spread the contacts until there is definite but very small movement of the outside leaves when the moving contact is operated back and forth.

Now adjust the remaining three sets, with slightly smaller but equal gaps, keeping in mind that they should work in unison. It is extremely important that, though these gaps are not as great as those of the meter relay contacts, they must be adjusted so that all contacts of one set can never touch at the same time; otherwise bridging may occur which will short the power supply and may cause contacts to weld.

K103 through K107 - These relays have two sets of contacts which are connected in parallel for reliability. The object is to adjust both contact sets so they operate in unison, while making the gaps as large as possible.

Actuate the armature only as described above to open the normally closed pairs. Adjust gaps so the four outside contacts move definitely but only slightly.

Symptoms Of Malfunction

The following list of possible troubles should be of considerable help to the service technician in efforts to repair an instrument. Before attempting repairs, however, study the section, "THEORY OF OPERATION". A thorough understanding of how the instrument works is valuable in tracking down and correcting faults.

Symptom	Probable Fault And Cause
Input Amplifier	
1. Instrument reads full scale positive at all times.	Q4 shorted - replace. Usually due to application of high input voltage when resistance measuring model is set to an ohms range. Also may occur when input is "floated" more than 1000 volts off ground.
2. Instrument drifts at a steady rate toward + or - full scale. Drift may change or reverse when "SET ZERO" adjuster is turned. May happen on one range only or all ranges.	A. Feedback circuit shorted to ground. Check for shorts between range resistors and "0" volts line or to case. Also check for short in shielded wire to FET socket. Check for points where wire insulation may be pierced. Also check C2 for short circuit. B. Feedback circuit open. Check for continuity from Q4 collector through range resistor, range switch, resistor R10, to FET plug-in unit.
3. Sensitivity very low or zero. May drift erratically.	Polystyrene capacitor shorted or leaky (C3 or C11). Capacitor may have been over-voltaged (see 1 above) or mechanically damaged as with a soldering iron. Replace only with polystyrene.
Digitizing & Readout Circuits	
4. Analog meter (M101) goes off scale before switching occurs <u>on some steps only</u>; OK on other steps. No steps are actually missed.	One or more comparators and relay drivers defective. Use Table I to pinpoint which comparator-relay system is at fault. Matched pairs of transistors may be unbalanced due to overload (see 1 above).

5. As above, but some steps are completely skipped.	Follow 4 above but look for inoperative relay or shorted or open relay driver transistor. If transistor is defective, also check the diode that shunts the relay coil.
6. Analog meter goes off scale in one direction or the other before switching occurs on all steps.	±6.4 volt supply may be unregulated due to defective component, especially Q202. ±6.4 volt supply may be oscillating due to defective capacitor, especially C201 or C203. +50 V supply may not be regulating, giving excessive voltage. This voltage should be about 48 to 56 V measured from "0" volts line. Check Q201 for possible short.
7. Analog meter moves slightly when power is turned on. Instrument is otherwise completely dead. Fuse is OK.	Power supply shorted from +6.4 V to -6.4 V points. Relay contacts may be welded lightly. Try to determine which relay before removing from socket as handling may clear the short. Replace relay or re-adjust contacts for wider gaps (see instruction on relay adjustment). Also check for other possible short circuits.
8. 320 ohms range inaccurate (reads low) near full scale but accurate over remainder of range.	Q4 has too much saturation resistance. Defective transistor or incorrect type installed.
9. Either meter sticky or digital meter (M102 fails to index properly at one or two points only.	Dirt or lint in meter movement. These are taut-band movements and have no pivots but are still subject to foreign particles.
10. Digital meter does not index correctly on many points.	A. Mechanical zero adjustment of movement may be off. Turn off instrument and short meter terminals or wait 10 minutes. Then adjust movement to line above 31 with extreme accuracy. B. Power supply not regulating. Check for 12.8 V ±.01 V between +6.4 V and -6.4 V lines. C. R160 incorrectly adjusted or has developed contact resistance. Rock rotor back and forth 10 times to clean contact surfaces, then adjust according to calibration step 3.
11. Analog meter does not drop or rise exactly 100 points when stepping occurs. This occurs equally on all steps.	See 10B and 10C above except adjust R108 according to calibration step 4.
12. Analog meter drops and rises more or less than 100 points on some steps only (or on all steps alternating from over 100 points to under 100 points).	Inaccurate resistor in group R128 through R132. Use Table I to pinpoint the highest numbered resistor that may be involved. Also check contact voltage drop in corresponding relay. Caution: soldering heat may correct a defective resistor, but only temporarily.
13. Instrument does not read 0 correctly in one polarity when carefully zero adjusted in the other polarity.	A. Right-hand (analog) meter not mechanically zeroed. Turn off instrument and short meter terminals or wait 10 minutes then adjust movement to 0 with extreme accuracy. B. Refer to calibration step 6.

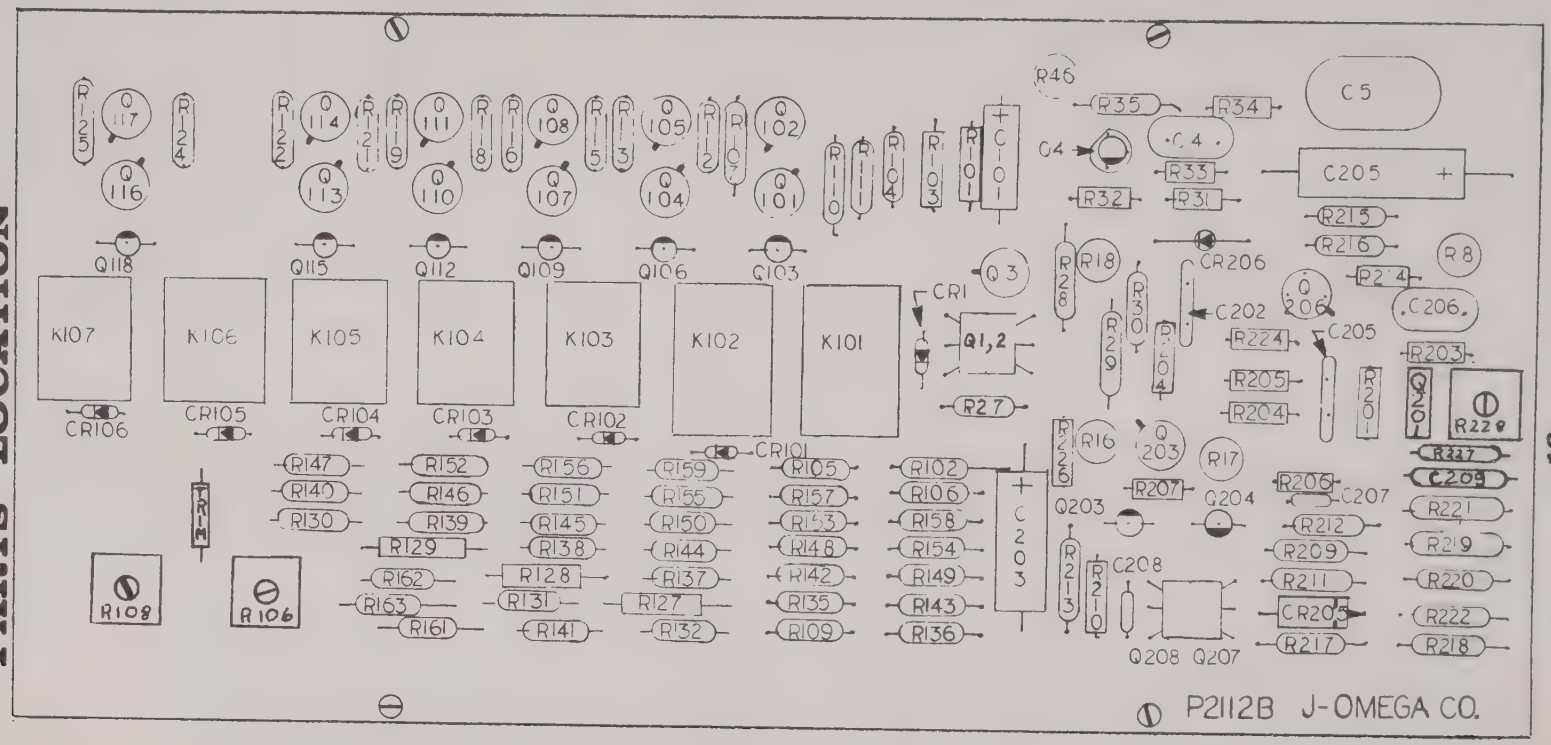
Regulated Power Supplies

14. Voltage calibration incorrect equally on all ranges. (Ohms calibration OK if unit has ohms ranges).	A. Check power supply from +6.4 V to -6.4 V. Should be 12.79 to 12.81 volts. Errors may be due to shifts in CR205, R220, R222 or possibly other components. Before re-trimming, make sure that voltage does not drift with time and temperature. Especially make sure that CR205 voltage remains very constant as unit warms up; this should not drift more than about 2 or 3 mV. Heat a suspected component to see if this causes large power supply changes or drift. B. If power supply is OK, re-trim R8 according to calibration step 9.
15. Voltage calibration changes as instrument warms up.	A. Power supply component changing with temperature. Monitor 12.8 V power supply voltage; it should not drift more than about 5 mV over normal temperature range. See 14A above. B. Check Q202 for excessive leakage.
16. Voltage calibration fails after unit warms up, especially at high line voltages.	Check Q202 for excessive leakage. Also monitor for possible power supply oscillation due to internal defect in C201.
17. Relays buzz severely near switching points (Note: A very slight buzzing sometimes occurs and is normal).	A. Power supply producing excessive hum and ripple, especially +50 V supply. Q201 may be defective. (Note: +50 V supply will "follow" the 12.8 V supply and will duplicate its hum and drift, therefore, first test the 12.8 V supply from +6.4 V to -6.4 V points; hum, ripple and noise on 12.8 V supply should be about 1 mV or less, and about 25 mV or less for +50 V supply). B. Power supply oscillating. Probably due to defective capacitor.

Switching Analysis

The Component Groups Below Produce Switching	... Between These Points (Positive Or Negative)
Q116-Q118, K107, R124, R125, R135-R141, R160-R162, CR106	0 and 1, 2 and 3, 4 and 5, 6 and 7, 8 and 9, 10 and 11, 12 and 13, 14 and 15, 16 and 17, 18 and 19, 20 and 21, 22 and 23, 24 and 25, 26 and 27, 28 and 29, 30 and 31
Q113-Q115, K106 R121, R122, R142-R147 CR105	1 and 2, 5 and 6, 9 and 10, 13 and 14, 17 and 18, 21 and 22, 25 and 26, 29 and 30
Q110-Q112, K105 R118, R119, R148-R152, CR104	3 and 4, 11 and 12, 19 and 20, 27 and 28,
Q107-Q109, K104, R115, R116, R153-R156, CR103	7 and 8, 23 and 24
Q104-Q106, K103, R112, R113, R157-R159, CR102	15 and 16
Q101-Q103, K101, K102, R104-R107, R110, R111, C101, CR101	-0 and +0 (Polarity)

Table I



REAR INTERNAL VIEW

PARTS LIST

(See Manufacturers Code on last page)

	CAPACITORS	MFR & P/N	QUAN.
C1	.039mf, 100v mylar	Sprague 225P39391	1
C2	.027mf, 600v mylar-paper	Sprague 6PS-S27	1
C3	.01mf, 500v polystyrene	Centralab CPR	1
C4	0.1mf, 100v mylar	Sprague 225P10491	2
C5	.25mf, 200v mylar	Sprague 2PS-P25	1
C6	5pf, 500v mica	Corn.-Dub.	1
C11	100pf, 500v polystyrene (in Types 217, 219, 413 and 415)	Centralab CPR	1
C101	25mf, 6v electrolytic	J-O P5050	1
C201	900mf, 35v electrolytic	J-O P5017	1
C202	2.2mf, 3v ceramic disc	Sprague HY150	2
C203	150mf, 15v electrolytic	J-O P5042	1
C204	20mf, 100v electrolytic	J-O P5044	1
C205	same as C202		
C206	same as C4		
C207	.01mf, 100v ceramic disc	Sprague TG-S10	3
C208	same as C207		
C209	22mf, 15v tantalum	Kemet K22C15K	1
C210	same as C207		
C211	.001mf, 1000v ceramic disc	Sprague	1

	RECT & DIODES	MFR & P/N	QUAN.
CR1	1N34A or similar	General Instrument	1
CR101	1N4148	GE	1
CR102	same as CR101		
CR103	same as CR101		
CR104	same as CR101		
CR105	same as CR101		
CR106	same as CR101		
CR201	1N4004	Diodes, Inc.	6
CR202	same as CR201		
CR203	same as CR201		
CR 204	same as CR204		
CR205	1N938	Siemens	1
CR206	same as CR201		
	TRANSISTORS		
FET 1	2N3958		1
Q1,2	Dual Transistor	Sprague TD-401	1
Q3	Selected MPS404	J-O P-3023	1
Q4	2N3415 or 2N2222	GE	1
Q101,2	matched pair MPS404	J-O P-3034	6
Q103	2N3415	G	8
Q104,5	same as Q101,102		
Q106	same as Q103		
Q107,8	same as Q101,102		
Q109	same as Q103		
Q110,111	same as Q101,102		
Q112	same as Q103		

	TRANSISTORS	MFR & P/N	QUAN.
Q113,4	same as Q101,102		
Q115	same as Q103		
Q116,7	same as Q101,102		
Q118	same as Q103		
Q201	D43C3	GE	2
Q202	same as Q201		
Q203	MPS404	Motorola	2
Q204	same as Q103		
Q205	same as Q103		
Q206	same as Q203		
Q207,8	same as Q1,2		
	RESISTORS		
R1	film type, 51.1K, 1/8w, 1%	D	1
R2	composition, 22M, 1/4w, 10%	A-B	2
R2A	same as R2		
R3	wirewound 1.2K	Dale RS-2B	2
R4	multi-turn, 50K, composition	J-O P4047	1
R5	same as R3		
R6	metal film, 4.95M, 2w, 1%	J-O P4032	2
R7	same as R6		
R8	variable, 250K, cermet	Helipot 72PMR250K	1
R9	composition 3.3M, 1/4w, 10%	A-B	1
R10	composition 4.7M, 1/4w, 10%	A-B	1
R11	metal film, 9.9M, 2w, 1%	J-O P4033	2
R12	same as R11		
R13A,C	film type, 800K, ½w, 0.1%	RN55C	2

	RESISTORS	MFR & P/N	QUAN
R13B	film type, 392K	RN55C	1
R14	metal film, 196K, 1/2w, 1%	J-O P4035	1
R15	wirewound, 18K, .02% (in Types 213, 215, 217, and 219)	J-O P4053	1
R16	variable, 500K cermet	Helipot 72PMR500K	1
R17	variable, 50K cermet	Helipot 72PMR50K	1
R18	variable, 5K cermet	Helipot 72PR5K	1
R20	wirewound, 320 ohm, .02% (in Types 213, 215, 217 and 219)	J-O P4061	1
R21	wirewound, 10,666.7 ohm .02% (in Types 213, 215, 217 and 219)	J-O P4062	1
R22	omit		
R23	wirewound, 2,461.54 ohm, .02% (in Types 213, 215, 217 and 219)	J-O P4063	1
R24	omit		
R25	omit		
R26	omit		
R27	film type, 12.7K, 1/8w, 1%	D	2
R28	film type, 20K, 1/8w, 1%	D	1
R29	film type 475 ohm, 1/8w, 1%	D	4
R30	film type 261 ohm, 1/8w, 1%	D	2
R31	carbon film 1.5K, 1/4w, 1%	B	4

	RESISTORS	MFR & P/N	QUAN.
R32	same as R31		
R33	carbon film 100 ohm, 1/4w, 5%	B	1
R34	carbon film 10 ohm, 1/4w, 5%	B	4
R35	same as R27		
R36	omit		
R37	omit		
R38	film type, 2K, 1/8w, 1% (in Types 413 and 415)	D	1
R39	wirewound, 20K, .02% (in Types 413 and 415)	J-O P4055	1
R40	same as R34		
R41	27K,5%,¼w,carbon film	B	1
R42,3,4	31.6K,1% metal film	RN55D	3
R45*	523K,½w,1% T-2 metal film	Dale	1
R46*	50K var.comp.	Helipot 78PR50K	1
R47	encapsulated high voltage resistor 100M (in Types 215,219,415)		
	J-O P-2103B(P2104 in -16)		1
R48,49	100K,5%,¼w,carbon film	B	2
R101	same as R34		
R102	film type, 100 ohm, 1/8w, 1%	D	1
R103	carbon film 6.8K, 1/4w, 5%	B	1
R104	film type 51.1K, 1/2w, 1%	D	6
R105	film type, 400 ohm, 0.1%	J-O	7
R106	same as R105		
R107	film type, 1.50K, 1/8w, 1%	D	6
R108	variable, 50 ohm, cermet	Helipot 72PR50	1
R109	film type, 6.4K, 0.1%	J-O P4074	6
R110	film type, 100K 1/8w, 1%	D	1
R111	same as R30		
R112	same as R104		
R113	same as R107		
R115	same as R104		
R116	same as R107		
R118	same as R104		
R119	same as R107		
R121	same as R104		
R122	same as R107		
R124	same as R104		
R125	same as R107		
R127	wirewound, 200 ohm, .02%	J-O P4064	1
R128	wirewound, 400 ohm, .02%	J-O P4065	1
R129	wirewound, 800 ohm, .02%	J-O P4066	1
R130	film type, 1.6K, 0.1%	J-O P4072	6
R131	film type, 3.2K, 0.1%	J-O P4073	5
R132	same as R109		
R135	same as R109		
R136	same as R109		
R137	film type, 213.33 ohm, 0.1%	J-O P4069	1
R138	same as R105		
R139	film type, 800 ohm, 0.1%	J-O P4071	6

* used in Types 217,219,413 & 415

	RESISTORS	MFR & P/N	QUAN.
R140	same as R130		
R141	same as R131		
R142	same as R109		
R143	same as R109		
R144	same as R105		
R145	same as R139		
R146	same as R130		
R147	same as R131		
R148	same as R131		
R149	same as R131		
R150	same as R105		
R151	same as R139		
R152	same as R130		
R153	same as R130		
R154	same as R130		
R155	same as R105		
R156	same as R139		
R157	same as R139		
R158	same as R139		
R159	same as R105		
R160	variable 500 ohm,	Helipot 72PR500	1
R161	film type, 6.19K, 1/8w	D	2
R162	same as R161		
R163	film type, 402K, 1/8w, 1%	D	1
R201	carbon film 33 ohm, 1/4w, 5%	B	1
R202	omit		
R203	carbon film 15K, 1/4w, 5%	B	1

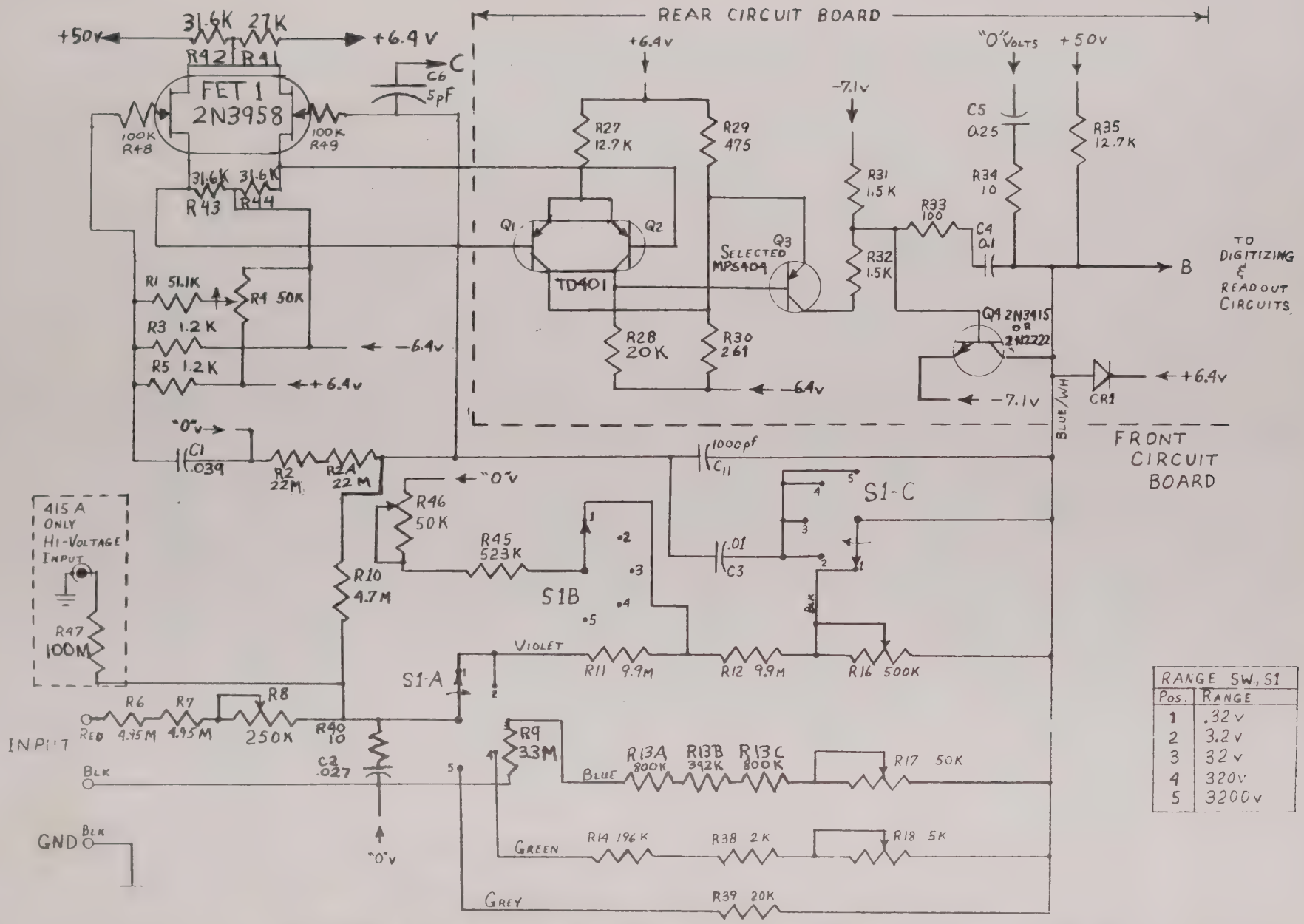
	RESISTORS	MFR & P/N	QUAN
R204	same as R34		
R205	same as R31		
R206	carbon film 4.7K, 1/4w	B	2
R207	carbon film 1K, 1/4w, 5%	B	1
R208	composition 2.7 ohm, 1/4w, 10%	A-B	1
R209	same as R29		
R210	same as R206		
R211	film type 931 ohm, 1/8w, 1%	D	1
R212	same as R29		
R213	same as R29		
R214	same as R31		
R215	film type, 12.1K, 1/8w, 1%	D	1
R216	film type, 3.01K, 1/8w, 1%	D	1
R217	stable type, value selected in manufacture		1
R218	film type, 475 ohm, 1/2w, 1%	D	1
R219	wirewound, 200 ohm, 0.1%	J-O P4075	2
R220	wirewound, 150 ohm, 1%	J-O P4080	1
R221	same as R219		
R222	wirewound, 50 ohm, 1%	J-O P4081	1
R224	composition 1 ohm, 1/2w, 10%	A-B	2
R225	omit		
R226	same as R224		
R227	carbon film 220K ¼w 5%	B	1
R228	variable cermet 2K Helipot 72PR2K		1

	OTHER COMPONENTS	MFR & P/N	QUAN.
F201	fuse, ½ amp Slo-Blo	Littlefuse	1
I101	lamp, 14.4v	G.E. 1813	2
I102	same as I101		
XI101	pilot light red(+)	J-O P8030	1
XI102	pilot light white(-)	J-O P8031	1
K101	relay, 4pdt	J-O P7010	2
K102	same as K101		
K103	relay, dpdt	J-O P7011	5
K104	same as K103		
K105	same as K103		
K106	same as K103		
K107	same as K103		

	OTHER COMPONENTS	MFR & P/N	QUAN
M101	meter, analog	J-O P7101	1
M102	meter, digital	J-O P7102	1
S1	switch, ten position, rotary (in Types 213 and 215)	J-O P7021	1
	(in Types 217 and 219)	J-O P7026	
	five position (in Types 413 and 415	J-O P7027	
S2	switch, toggle, dpdt (in Types 217 and 219	C&K 7201	1
S201	switch, toggle, spst	Cutler-Hammer 8280-K15	1
T201	transformer, 115v primary	J-O P6111	1

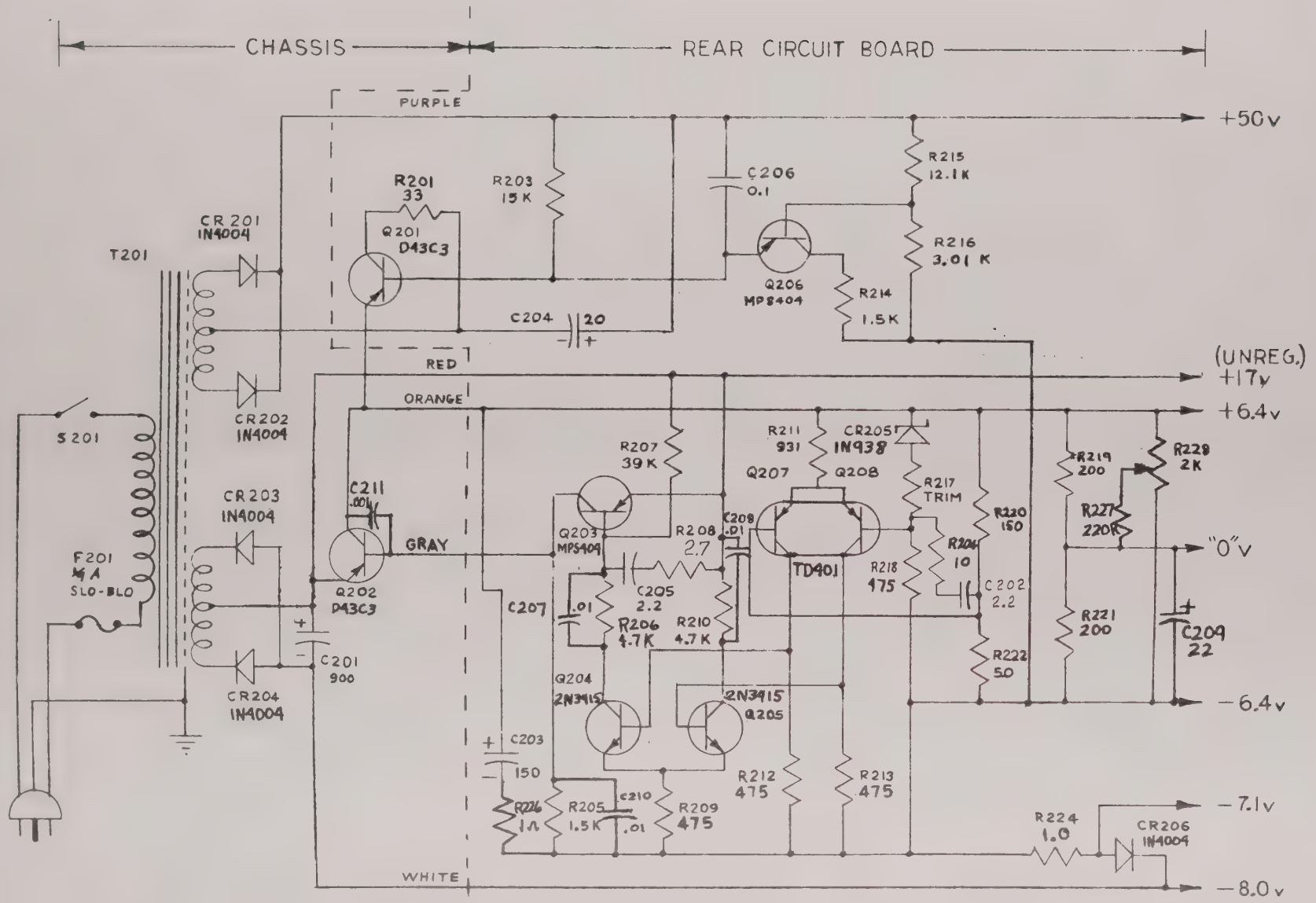
Manufacturers Code:

J-O J-Omega Company
A-B Allen-Bradley Company; Type CB (resistor)
B Behschlag (Dale) Type SBB (resistor)
D Dale Electronics, Inc.; Type MFF 1/8 (resistor)

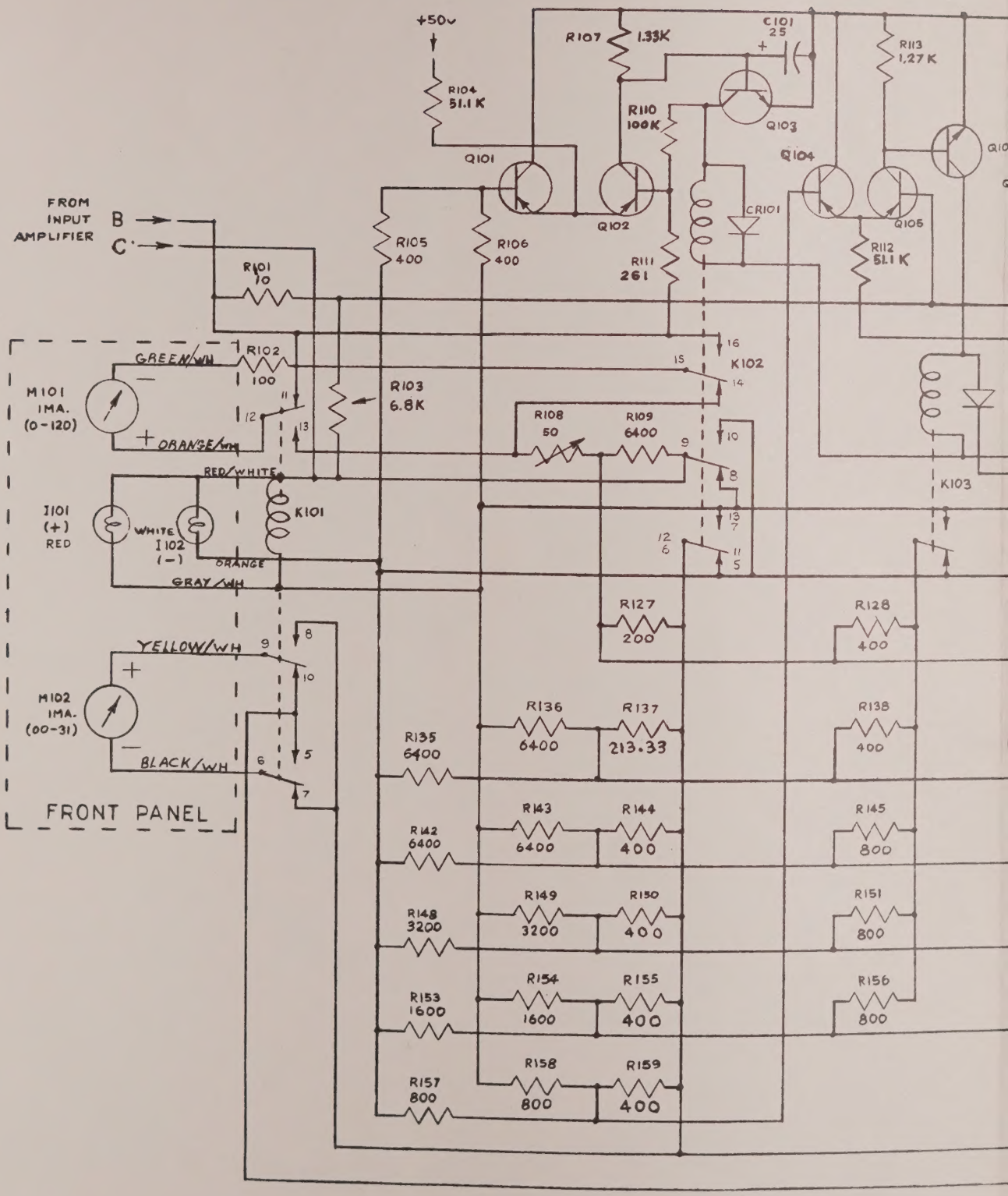


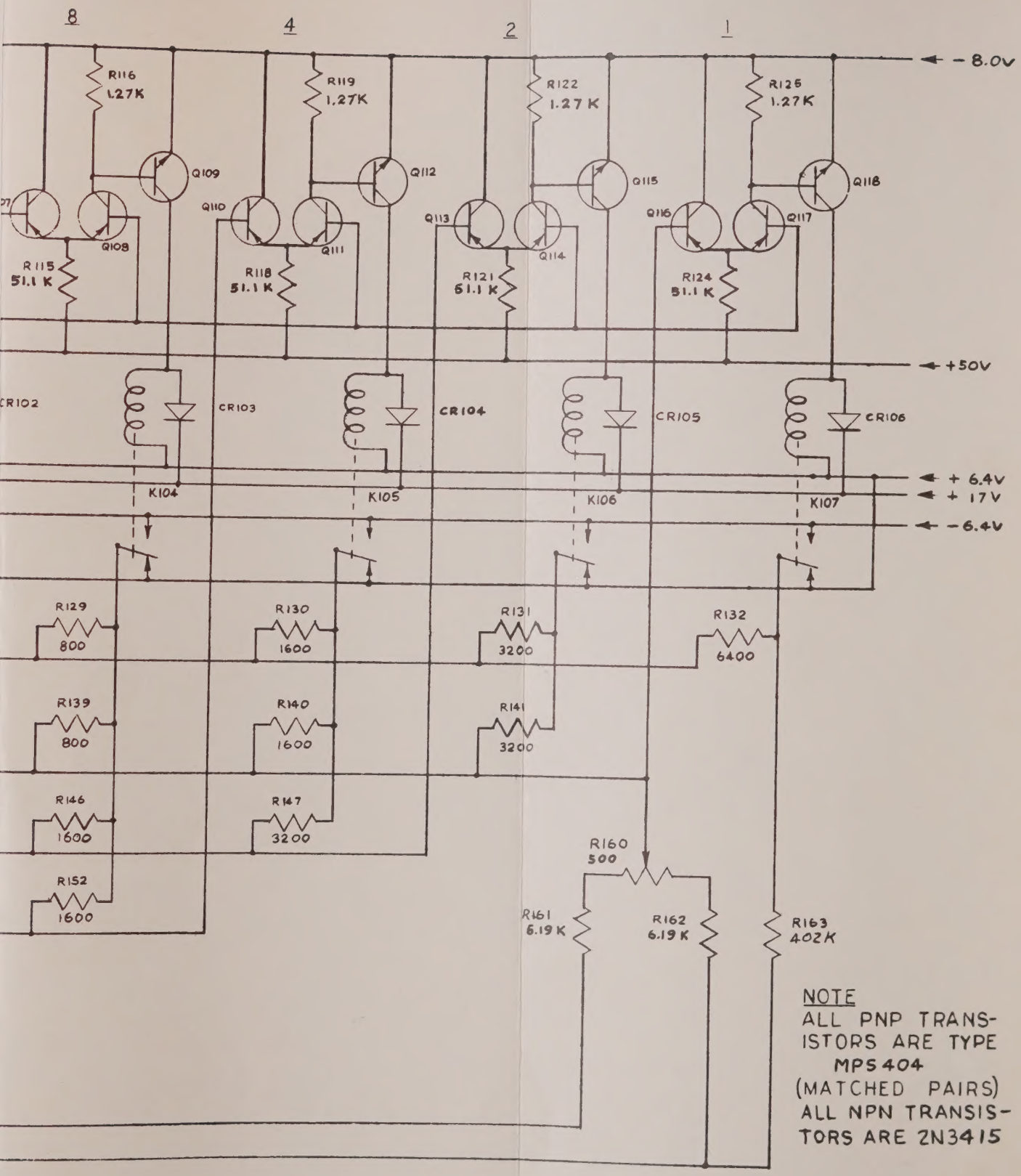
RANGE SW., S1	
Pos.	Range
1	.32 v
2	3.2 v
3	32 v
4	320v
5	3200v

413A & 415A AMPLIFIER AND RANGE SWITCH



REGULATED POWER SUPPLY


+50v
R104 51.1 K
R107 1.33K
C101 25
R113 1.27 K
R110 100K
Q101
Q102
Q103
Q104
Q105
CR101
R105 400
R106 400
R111 261
R112 51.1 K
FROM INPUT AMPLIFIER
B
C
R101 10
R102 100
R103 6.8K
GREEN/WH
ORANGE/WH
M101 IMA. (0-120)
RED/WHITE
K101
I101 (+) RED
WHITE
I102 (-)
ORANGE
GRAY/WH
K102
K103
R108 50
R109 6400
YELLOW/WH
BLACK/WH
M102 IMA. (00-31)
FRONT PANEL
R127 200
R128 400
R135 6400
R136 6400
R137 213.33
R138 400
R142 6400
R143 6400
R144 400
R145 800
R148 3200
R149 3200
R150 400
R151 800
R153 1600
R154 1600
R155 400
R156 800
R157 800
R158 800
R159 400



NOTE
ALL PNP TRANSISTORS ARE TYPE MPS404 (MATCHED PAIRS)
ALL NPN TRANSISTORS ARE 2N3415